Zinc-Air Secondary innovative nanotech based batteries for efficient energy storage [646186]

ZAS

Zinc-Air Secondary innovative nanotech based batteries for efficient energy storage

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SINTEF

Beyond Lithium Ion Workshop
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Storage of energy produced by decentralized sources

In the future electricity will be produced from geographically decentralized and intermittent energy sources.

- There will be a high demand for storage solutions which can:
  - improve the stability of weak grids
  - intentionally island the electricity distribution
  - ensure the continuity of energy supply.

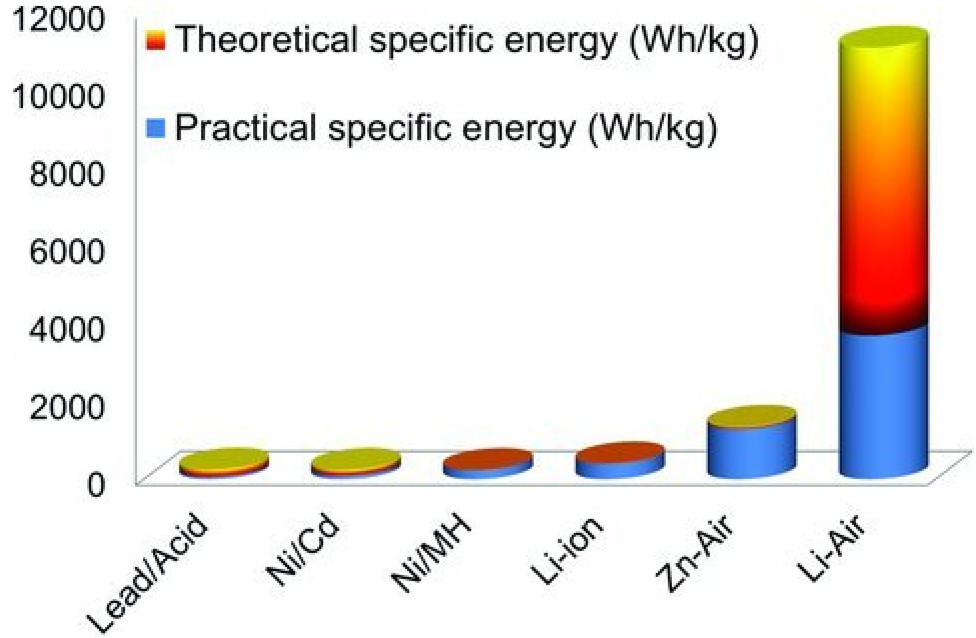
- Urgent need for storage technologies which are more available, better performing and more cost effective than todays solutions.

Zinc-Air Secondary innovative nanotech based batteries for efficient energy storage

Main goal:

Develop a secondary zinc-air battery system for efficient and cost effective stationary energy storage.

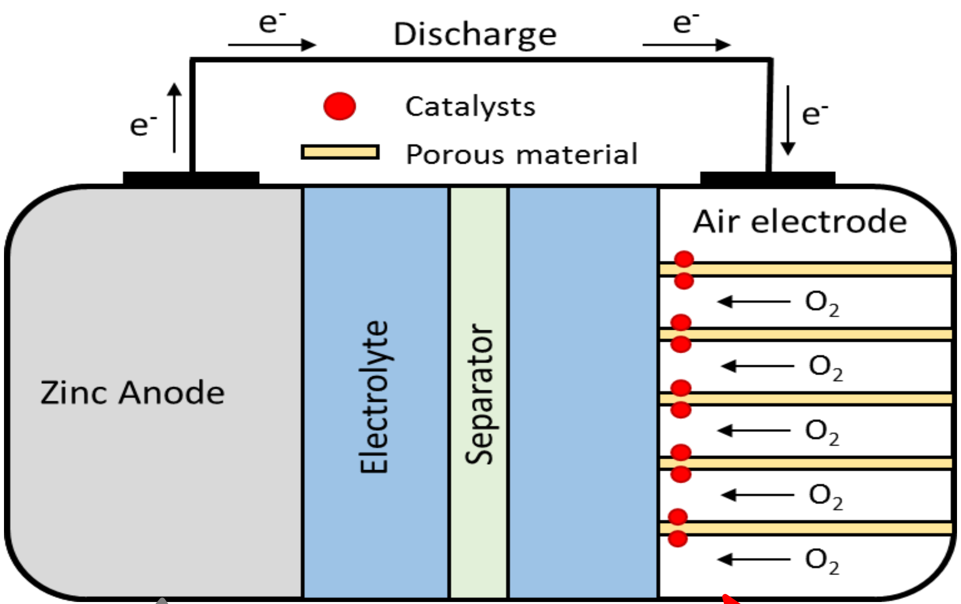
Why Zinc-air battery?



- High energy density
- Abundant and environmentally friendly materials
- Non-flammable and safe
- Low cost

Jang-Soo Lee, *Metal–Air Batteries with High Energy Density: Li–Air versus Zn–Air*, Adv. Energy Mater. 2011, 1, 34–50

Zinc-Air Secondary innovative nanotech based batteries for efficient energy storage



$Zn \longrightarrow Zn^{2+} + 2e^-$

$Zn^{2+} + 4OH^- \longrightarrow Zn(OH)_4^{2-}$

$Zn(OH)_4^{2-} \longrightarrow ZnO + H_2O + 2OH^-$

$E^0 = -1.25$ V vs NHE

$O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$

$2Zn + O_2 \longrightarrow 2ZnO$

$E^0 = 1.65$ V vs NHE

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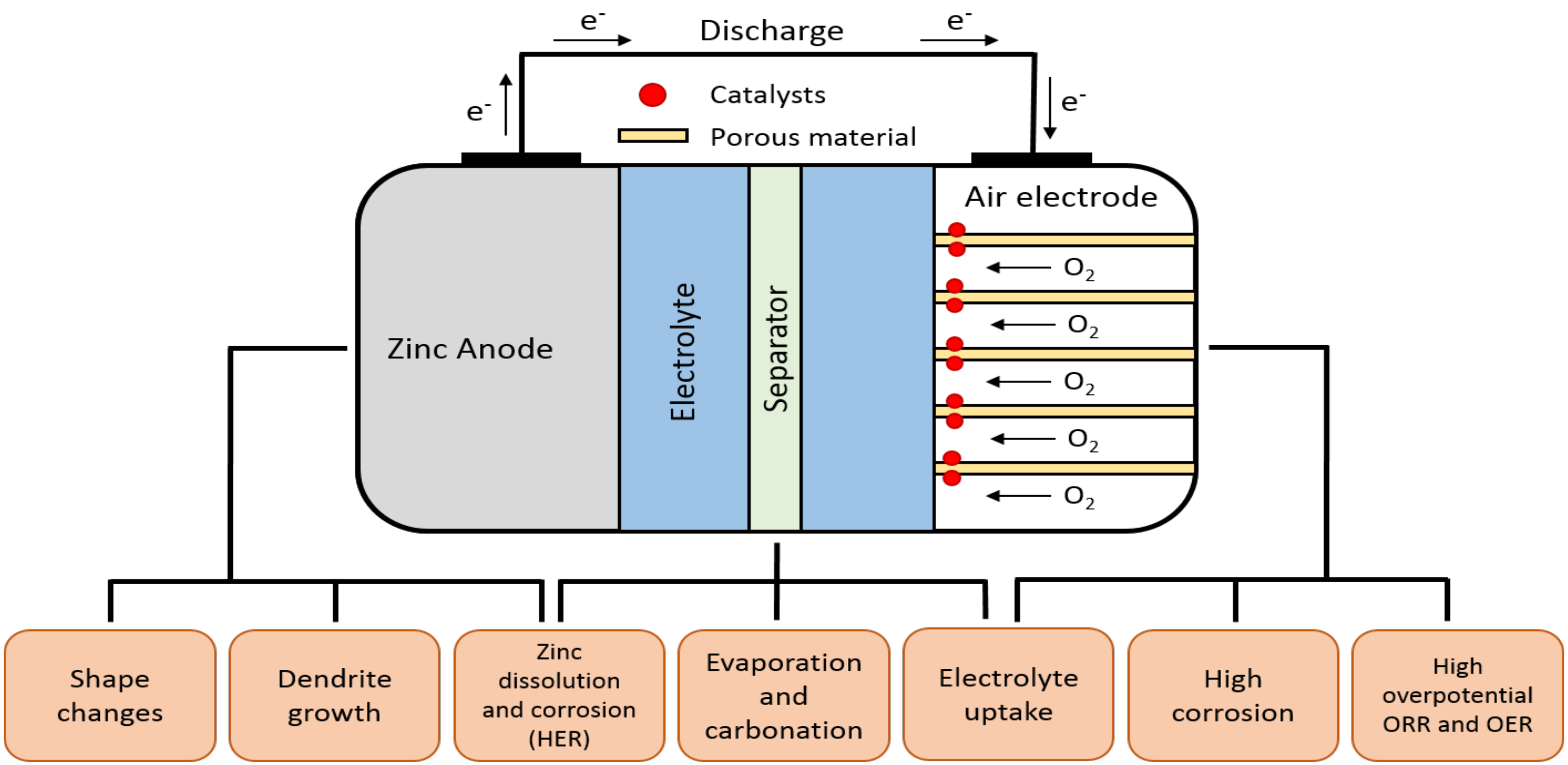
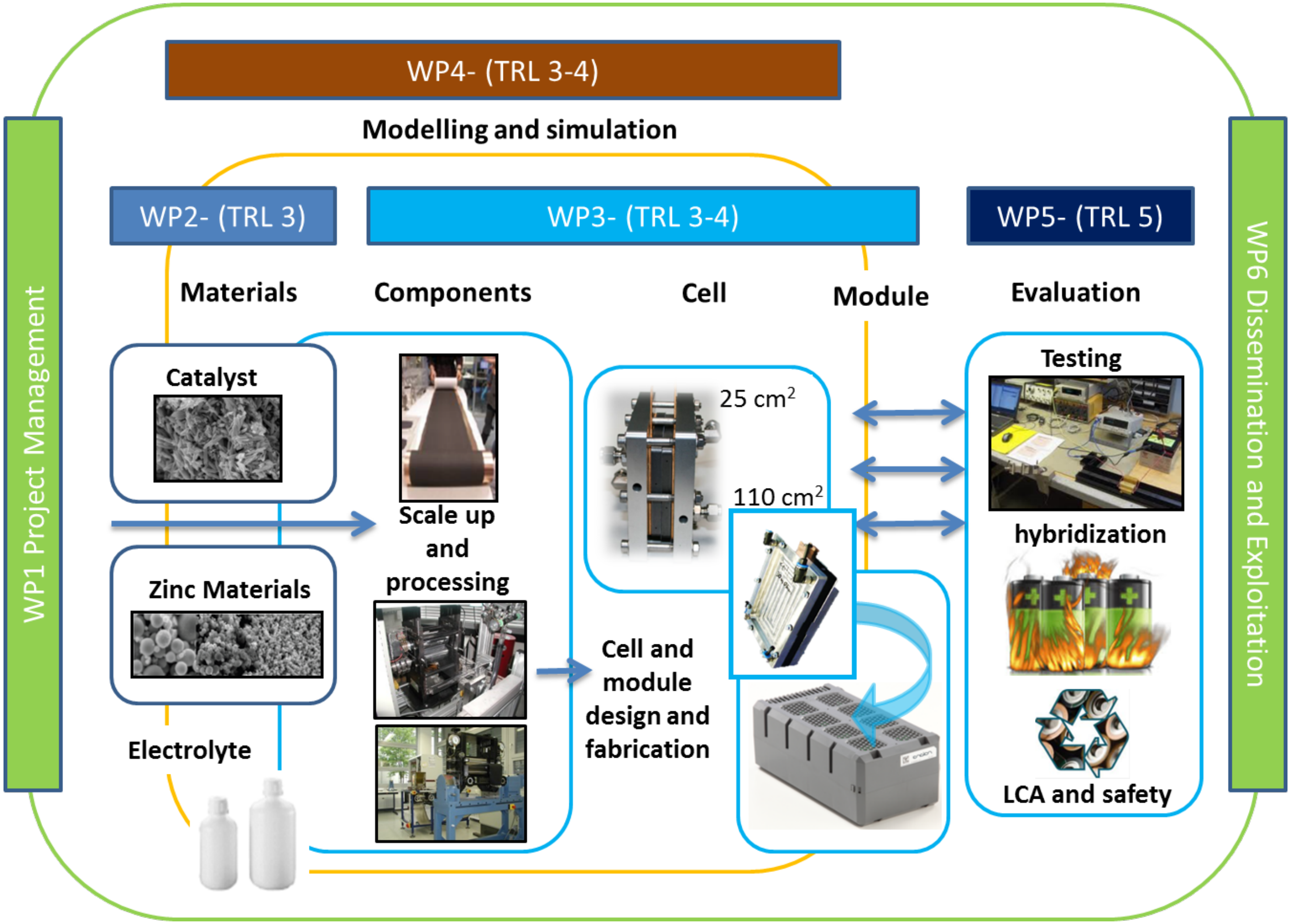
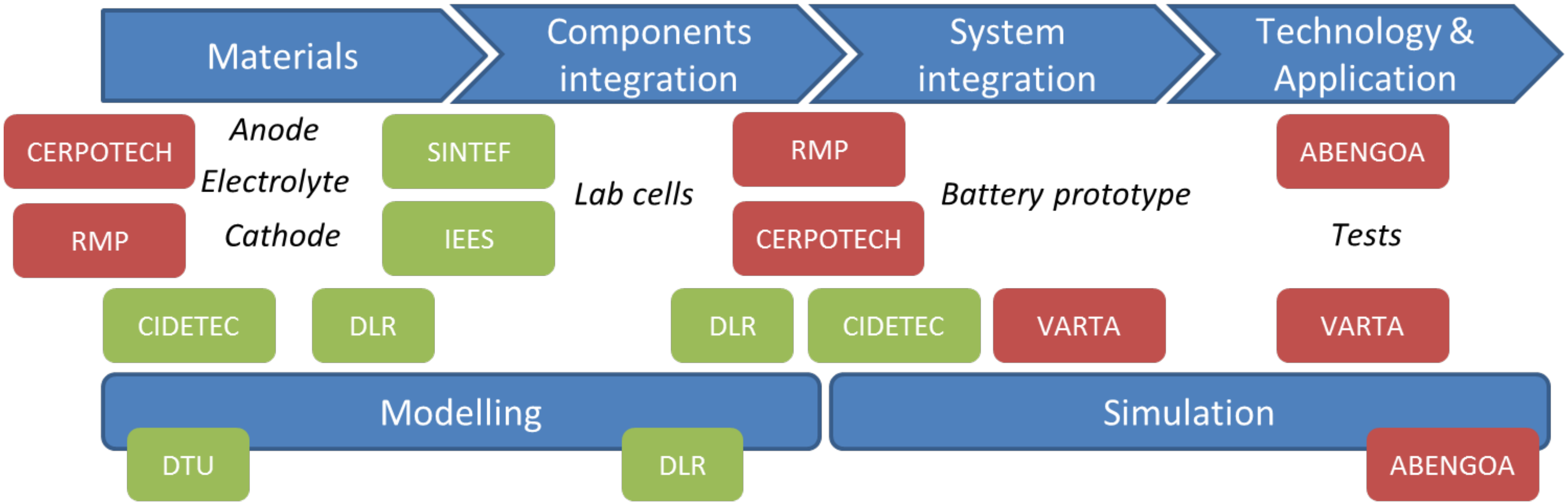


ZAS project: Covering the full value chain



ZAS project: Covering the full value chain



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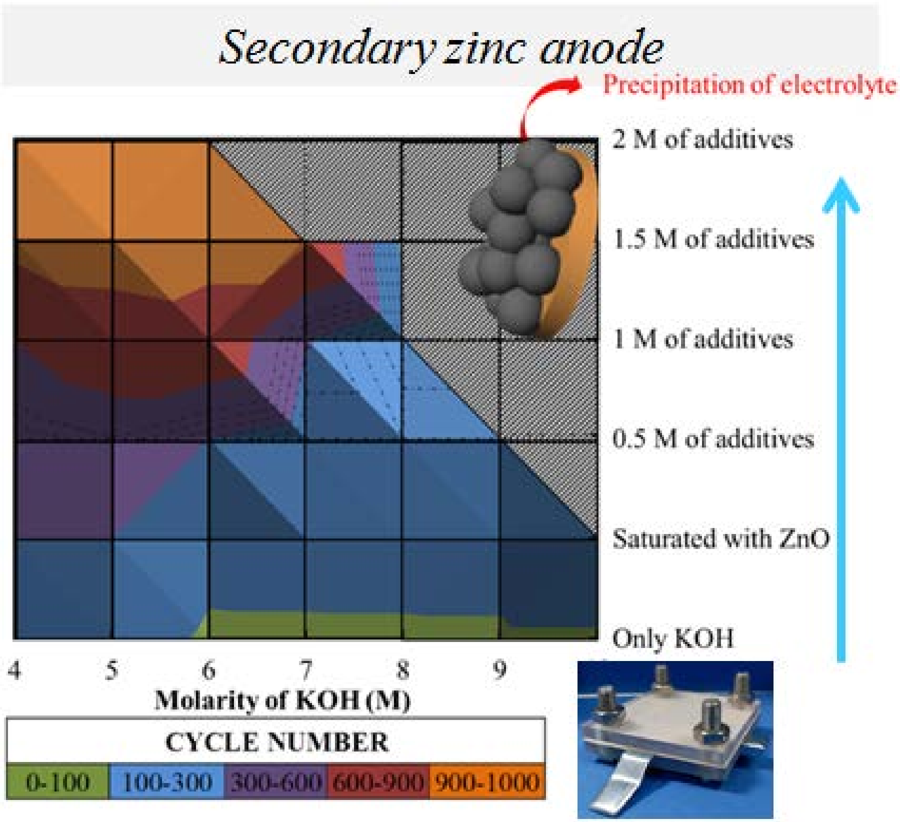
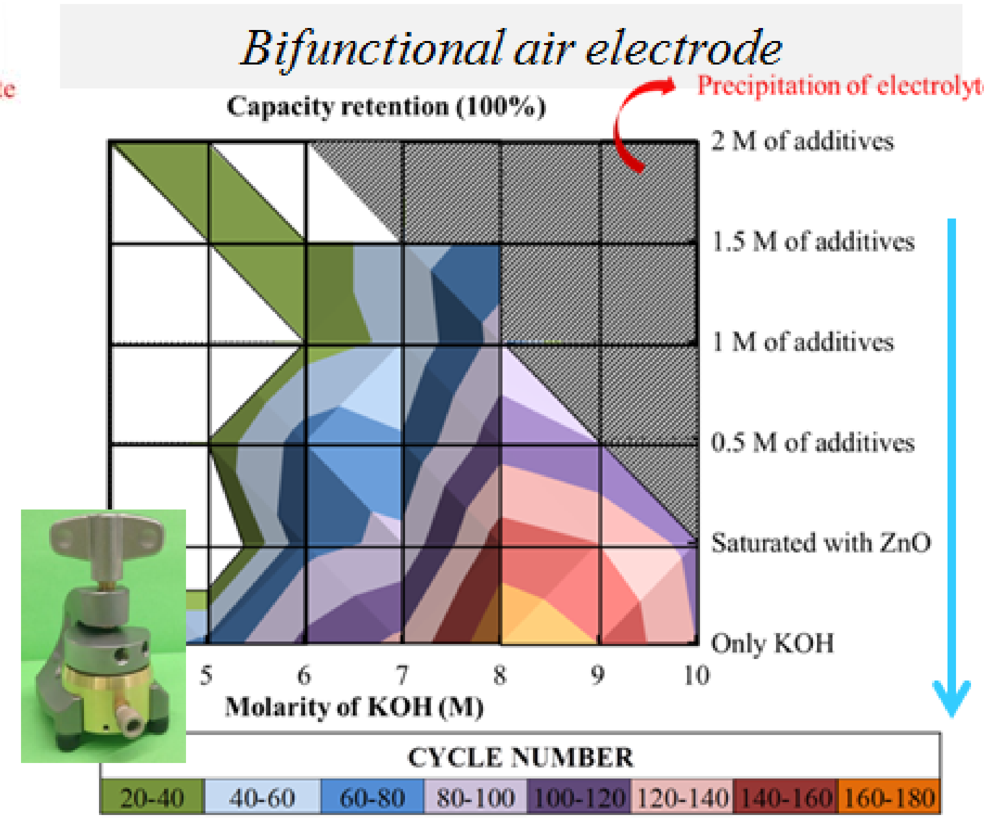
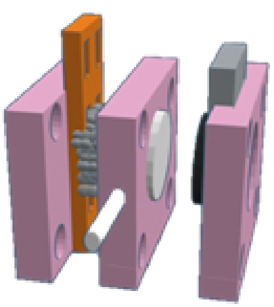
Optimization of alkaline electrolyte

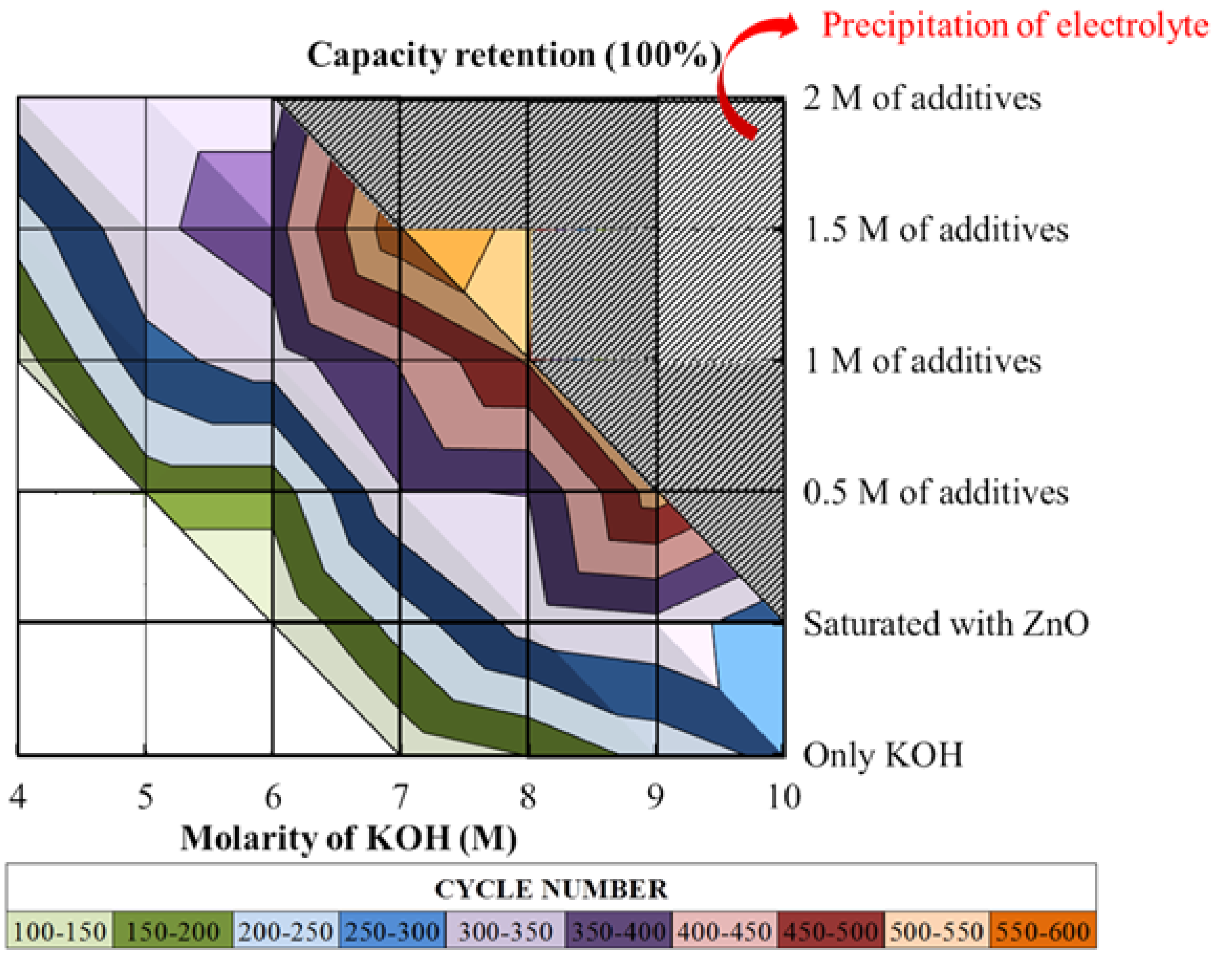




Aroa R. Mainar et al. *Systematic cycle life assessment of a secondary zinc-air battery as a function of the alkaline electrolyte composition*, Energy Science & Engineering (2018)

Optimalization of alkaline electrolyte

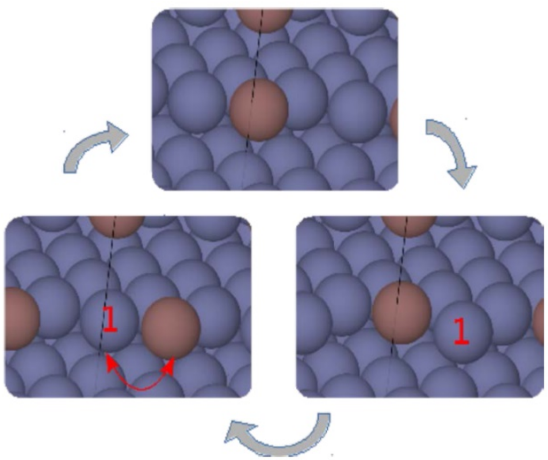




Aroa R. Mainar et al., Energy Science & Engineering (2018).

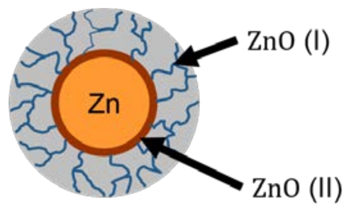
Zn anode design and role of additives

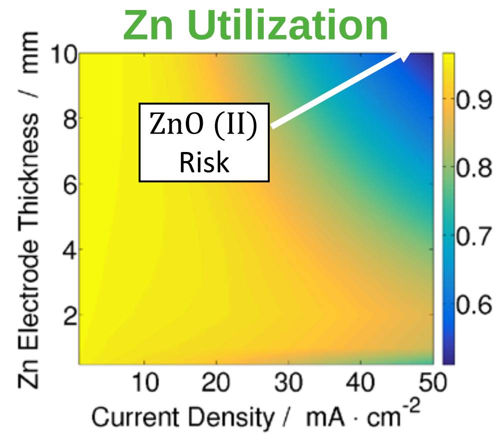
Zn anode and role of additives:



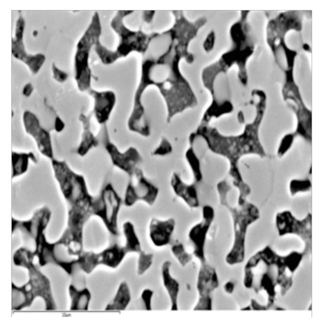
In and Bi is limiting the thermodynamic driving force for HER and remains on the Zn-surface during charging

Passivation of Zn anode:





Porous Zn anode :



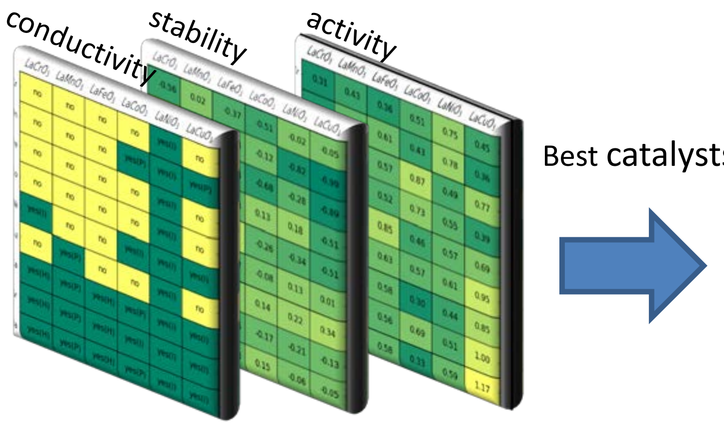
New anode design which shows potential for higher current density

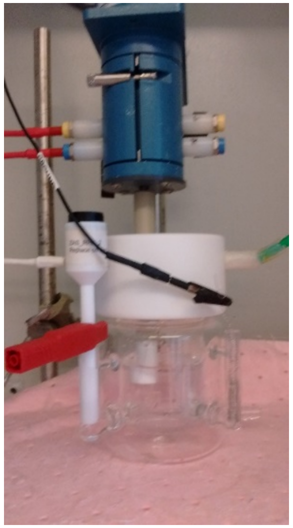
Steen Lysgaard et al. *Combined DFT and DEMS investigation of the effect of dopants in secondary zinc-air batteries*, ChemSusChem (2018) DOI 10.1002/cssc.201800225

Simon Clark et al., *A Review of Model-Based Design Tools for Metal-Air Batteries*, Batteries 4 (2018) 5

Screening of bifunctional catalysts

Screening of potential bifunctional catalyst by combining DFT calculations and experimental tests:

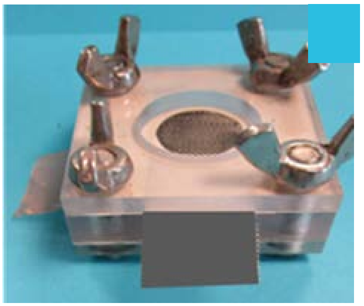




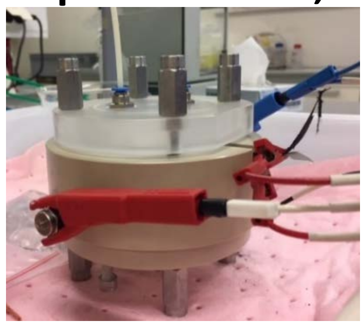
Vladimir Tripkovic et al. *From 3D to 2D Co and Ni oxyhydroxide catalysts: Elucidation of the active site and influence of doping on the oxygen evolution activity*, ACS Catal., 2017, 7 (12), pp 8558–8571
Vladimir Tripkovic et al., *Computational Screening of Doped α-MnO 2 Catalysts for the Oxygen Evolution Reaction*, ChemSusChem 2018 108, https://doi.org/10.1002/cssc.201701659

Lab scale validation in alkaline electrolyte

Verification of material performance, optimization of operation and upscaling:



1 cm^2



25 cm^2

182 cm^2

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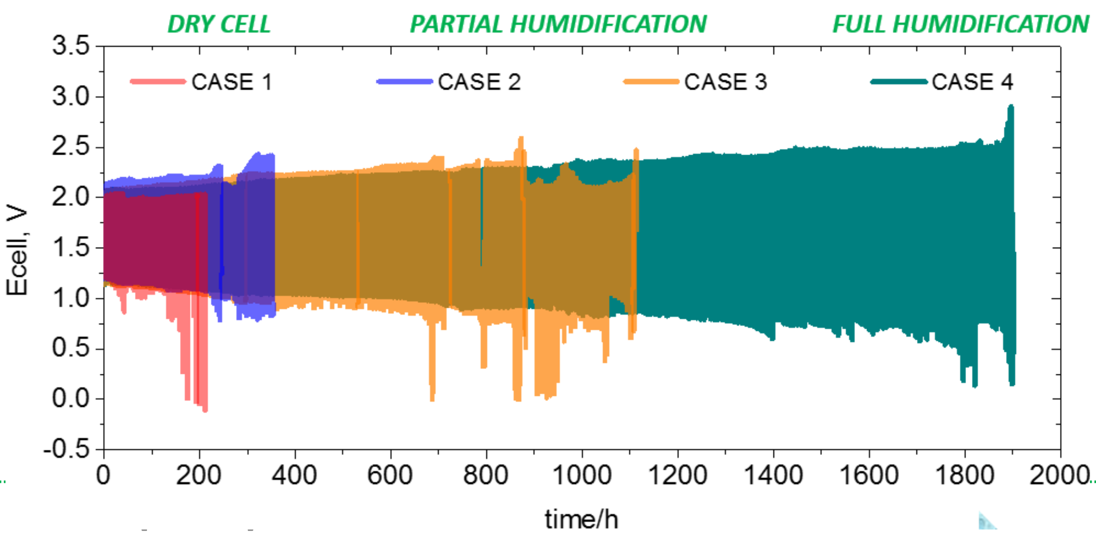
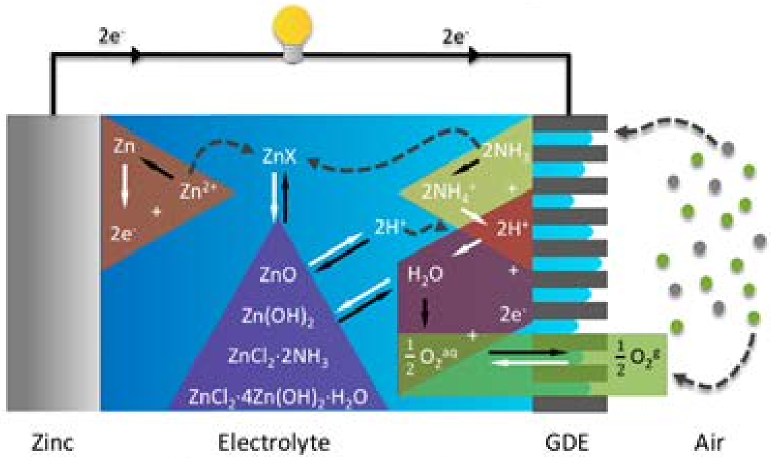
Unit cell (25cm^2) : More than 200 cycles with realistic operation condition and control of humidification:



~8h/cycle
C-rate : 1 mA/cm^2
Capacity: 65 mAh
(-) electrode: Zn-paste
(+) electrode: Ni/NCO

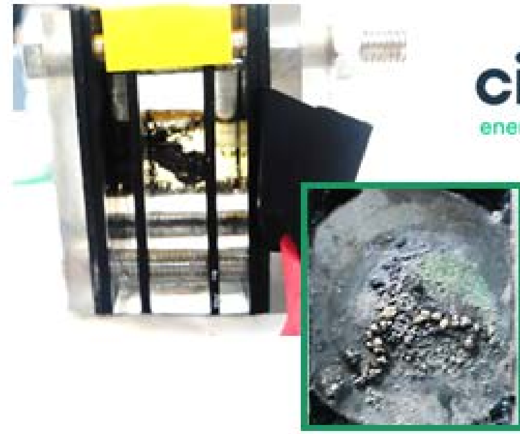
Beyond alkaline electrolyte - design of new electrolytes

Combining 1D continuum cell models with thermodynamical calculations



DLR

Experimental validation



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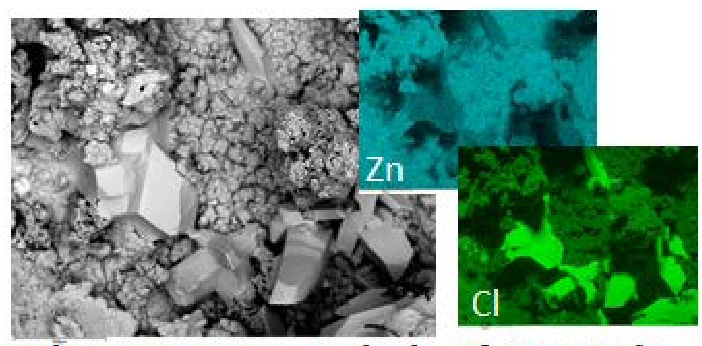

Microstructure analysis of Zn anode

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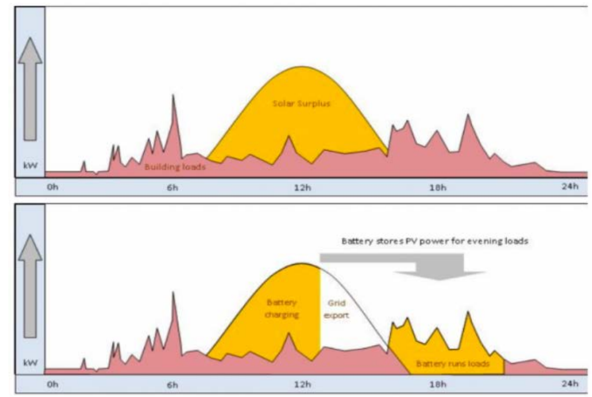
Simon Clark et al., *Rational Development of Neutral Aqueous Electrolytes for Zinc-Air Batteries*, ChemSusChem. 10 (2017) 4735-4747. DOI: 10.1002/cssc.201701468

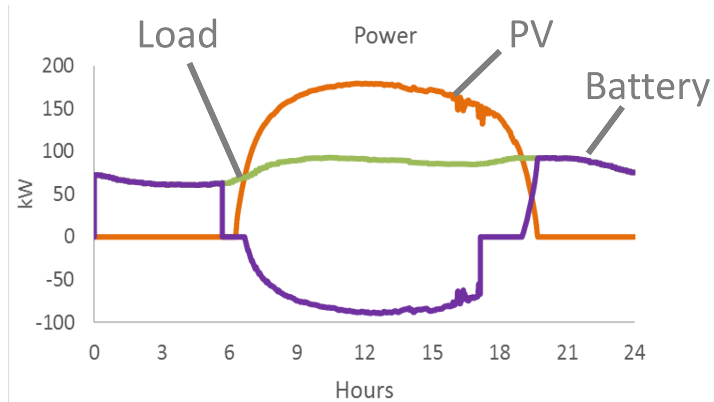
Feasibility of using zinc-air batteries for stationary storage

- The most representative energy storage applications were analyzed in order to identify potential applications of the ZAS technology:
  - Load following / ramping support for RES
  - Frequency regulation
  - Spinning reserve
  - Peak Shaving
  - Load shifting / arbitrage



- Simulation scenarios of the ZAS batteries toward a real 160 kWp PV plant and corresponding load demand:

System level	(modules: 8 series 24 parallel)	
Energy	1.651,200	kWh
Power	101,41	kW
Nominal Voltage	480,000	V
Internal resistance	0,035	Ω
Maximum current	218,544	A
Deep of discharge	40	%
SoC range	80-40	%



Summary

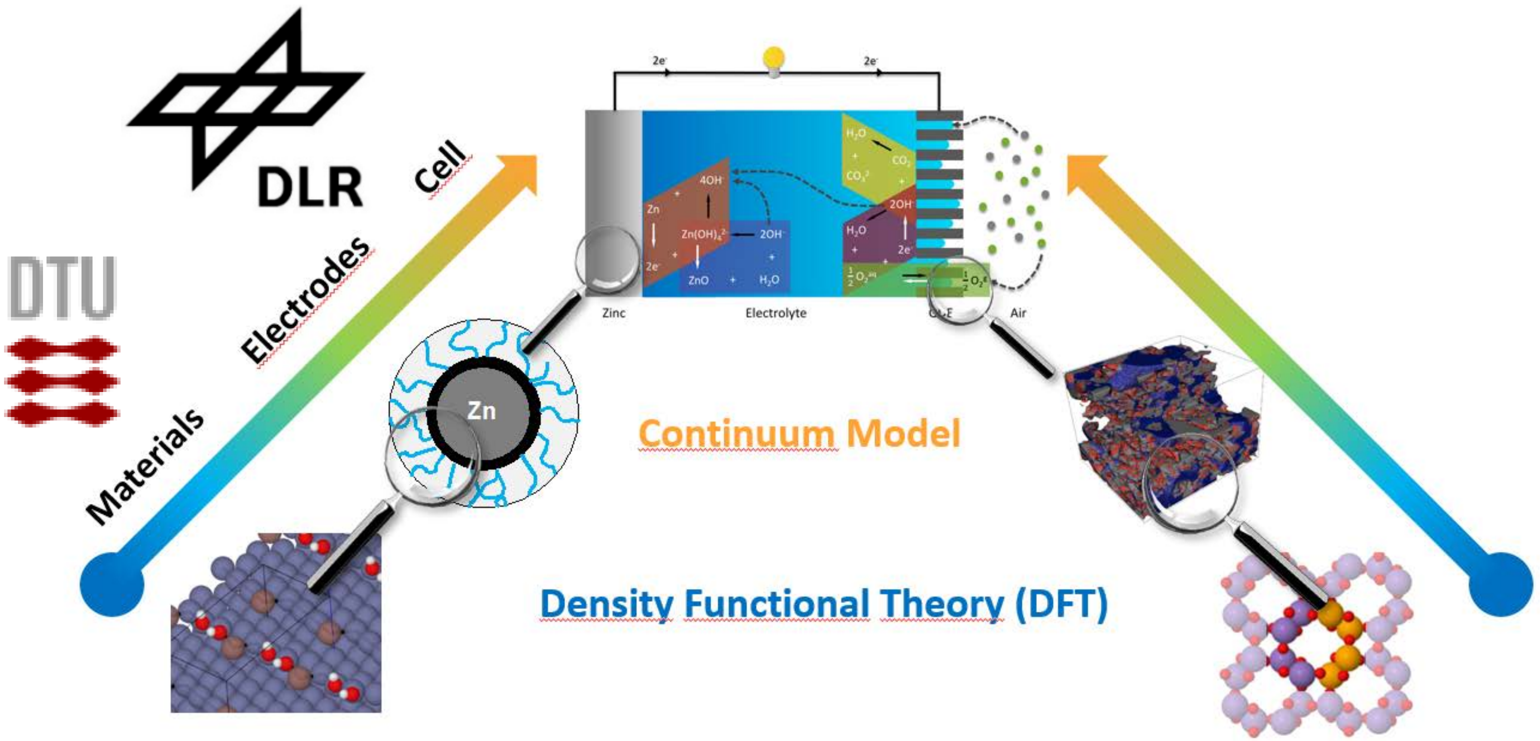
ZAS main achievements:

- Improved understanding of **how alkaline and near-neutral electrolyte compositions impact the overall performance of the battery**. The understanding of how the thermodynamics of electrolyte works can be extended and utilized for other battery chemistries and fuel cells.
- Developed methods for **efficient screening of oxide-based catalysts** by combining DFT calculations and efficient experimental testing procedures.
- Build fundamental understanding of the **effect of additives in the Zn anode** and **how the design of the anode influence its performance.**
- **Identified feasible application** for a zinc-air batteries in stationary energy storage systems.

Summary

ZAS main achievements:

- One of the first European projects to design a **Multi-Scale Modeling Platform** in the field of batteries.



Zinc-Air Secondary batteries based on innovative nanotechnology for efficient energy storage

The project is supported by the Horizon 2020 framework NMP program
European Commission – Grant Agreement no. 646186 - ZAS

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